ALIGNMENT TECHNIQUES FOR THE HIGH CURRENT AIRIX ACCELERATOR

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Abstract

AIRIX is a linear induction accelerator which will produce by the end of 1999, a 20 MeV, 3.5 kA, 60 ns electron beam for X-Ray Radiographic applications. The high performance required for the French Radiographic Hydrotest Facility is connected to the beam quality and thus to the accelerator alignment.To minimize corkscrew motion and emittance increase of the beam, mechanical and magnetic alignments have been performed to assemble and align the accelerator cells by using capacitive detectors such as HLS (Hydrostatic Levelling System) and WPS (Wire positionning System). In order to perform magnetic alignment, the streched wire technique has been developed for an automatic magnetic characterization of the cells. In this paper we will present and discuss the different alignment techniques but also the first results obtained

1 INTRODUCTION

The AIRIX induction LINAC will produce in Summer 1999, a 3.5kA, 20MeV, 60ns electron beam for flash X-ray radiography applications. This accelerator consists of 64 induction cells with a solenoidal focusing magnet and X, Y dipole steering magnets in order to perform the beam transport. The cells are assembled in blocks of 4 cells to obtain 16 blocks. The first 4 blocks were tested [1] at the beginning of 1999. The high beam quality requires low emittance increase (<10%) and energy spread (<1%). To achieve such performance, we must take care of the mechanical and magnetical alignments to minimize the chromatic effects. The goal is to enclose all the cell magnetic axes in a 250µm diameter cylinder with an angle spread less than 500µrad.

The solenoidal magnet is equipped with homogenizer rings, mechanically centered in the solenoid, to minimize the field errors. The cell magnetic axis is thus referenced to the mechanical one with a high accuracy ($Br/Bz < 8\ 10^{-4}$). So these two axes are considered as the same in the aligment procedure.

In this paper we will present the mechanical technique to align the cells and the blocks on the accelerator axis. The magnetic characterization of the cells and the results obtained with the first 8 cell-blocks will be developed

2 MECHANICAL ALIGNMENT

2.1 Cell block assembling

The cells are first assembled with locating pins on a standard mounting bench SMB to obtain a block of 4 cells [2]. This bench is equipped with two standard references. The cells are aligned and assembled with an error less than 30µm by using a laser and a moving CCD detector along the cell centerline. This accuracy includes the laser and the block positioning. In order to perform high accuracy block alignment all along the accelerator and control their position between two hydro-shots without breaking the vacuum, we define an external reference, ouside the blocks, by means of HLS (Hydrostatic Levelling System), WPS (Wire Positioning System) capacitive detectors and an inclinometer. These detectors define respectively the vertical, the horizontal and angular positions of the block. These positions are recorded on a block-data file with an accuracy of 10 µm due to thermal effects.

2.2 Block alignment on the accelerator

This procedure can be characterized by the following steps: -calibration of the standard accelerator references on the SMB;

-alignment of these references with a theodolite on the accelerator axis. This axis is defined by the centered normal injector cathod;

- alignment of the blocks with respect of these references by using its block data file.

The positioning error and the measurement sensitivity of the blocks are less than 10µm and 1 µm respectively.

A LabView program has been developed in order to control and follow the alignment continuously. The overall mechanical alignment accuracy is estimated at 50µm.

3 CHARACTERIZATION OF THE SOLENOIDAL MAGNETS

The aim is to characterize for each block, the offset and the tilt misalignments of the cell solenoid magnets with respect to the block axis by using the streched wire alignment technique [3] and cancel the tilt one with the steering magnets. The block axis is defined by the entrance and exit center block.

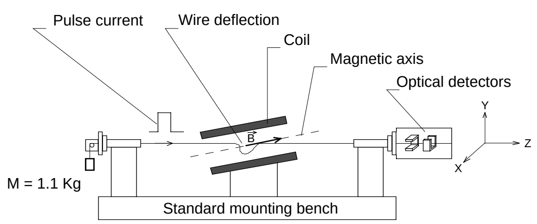

Figure 1: streched wire technique

3.1 Principle

A wire is centered on the solenoid mechanical axis. If this axis is different from the magnetic one, transverse magnetic fields occur. The method (Fig. 1) consists in sending a short pulse of current and observing the motion induced in the wire due to Lorentz force. In order to measure the wire deformations in the two transverse X and Y directions, two optical detectors are placed close to the wire. The typical flaws measured are an offset and/or tilt of the solenoid magnetic axis with respect of the wire which materialize the solenoid mechanical axis. The two types of flaws (Fig 2) are so different that they can easily be distinguished.

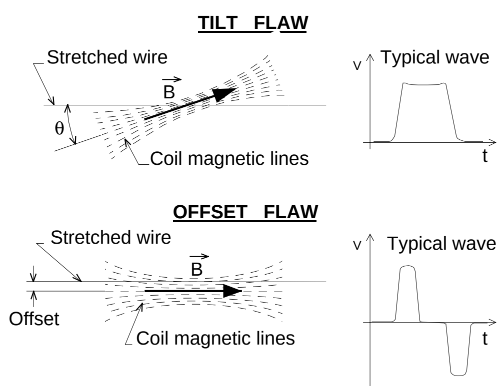

Figure 2: typical flaws

3.2 Procedures

The following steps for the 4 cells of each block must be achieved:

-center the wire on the block axis and then on a cell axis by taking into account the sag deformation of the wire;
-calibrate the optical detectors in a linear region;
-record the base line (deformations due to the external magnetic fields) by injecting a pulse current in the wire without a current in the solenoid. In order to eliminate the noise, we must average over several shots;
-measure the solenoid flaws with the base line substraction, by injecting the pulse current in the wire with a current in the solenoid and average over several shots for the noise substraction;
-calibrate the tilt and the offset flaws by moving the wire in the X and Y directions to obtain the desired flaws;
-apply X and Y dipole steering magnets in order to cancel the tilt signals produced by the cell solenoid magnet.

An automatic procedure with LabView has been developed to test the 16 blocks.

3.3 Experimental set-up

These measurements are made for each block on the SMB bench. We used a 125 µm diameter Cu(98)/Be(2) wire. This wire is tensioned by a 1100 g weight and centered at the two block ends by means of two polarized straight edges precisely located by locating pins. The positioning procedure consists in moving the wire until it makes an electrical contact with these polarized edges. These edges are made of a polished surface with a gold layer coating to increase the contact which is performed when a sinusoidal current is established. In order to avoid a stick effect between the wire and the edges, we used a 5V sinusoidal polarization. To align the wire in the two X, Y transverse directions, two isolated edges are required. By making a succession of 10 measurements, a standard deviation value less than 5µm is obtained. To take into account the sag deformation of the wire, we finally move the wire in the middle of the cell solenoid.

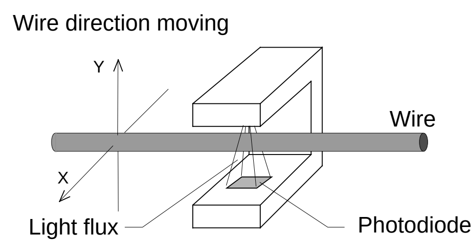

Figure 3: an optical detector

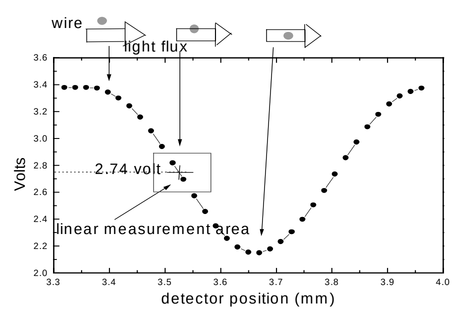

Figure 4: experimental detector calibration

The wire deflection is created by injecting a 5A, 300 µs pulse current. This deflection is determined by measuring its time-varying obstruction of the light beam (Fig. 3) which is generated and detected by a pair of orthogonal, small, cheap, optical detectors (Hamamatsu P3784).

This detector is calibrated in a region of linear response (Fig..4) by moving it in the two transverse X and Y directions by means of micrometers.

The signal of the detector is amplified with a gain of 100 and recorded on a AT-MIO-16E-2 DAQ National Instruments board sampling at 500kS/s with 12-bit resolution. The sensitivity of the detector/amplifier circuit is about 800mV/µm of wire deflection. The electronic noise, around 5mV, is very low compared to the noise generated by the structure's vibrations which can reach 1V. The eigen resonant frequency of the wire is 43Hz. To decrease the vibration noise level under 50mV, air cushions are placed under the SMB with an eigen resonant frequency of 2Hz. We also average over 20 measurements to cancel the statistical noise. The dead time between two pulses must be long enough (around 5s) to put the wire in quiet situation after all the damped reflected waves.

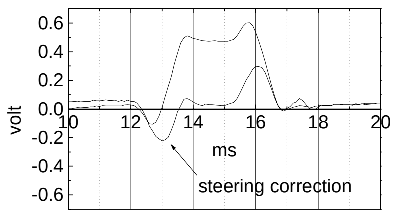

Figure 5: measured X flaws with and without steering correction

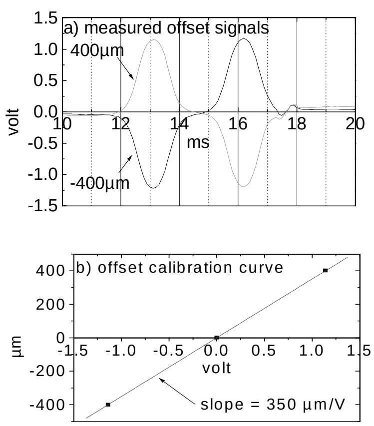

Figure 6a,b: experimental offset calibration

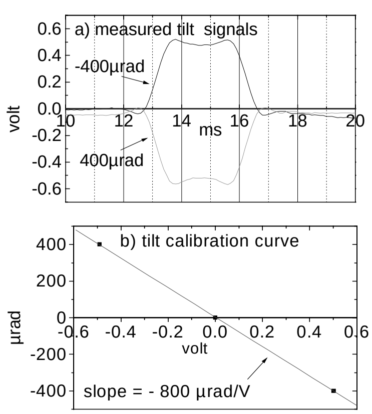

Figure 7a,b: experimental tilt calibration

3.4 Results

Measurements have been performed with a 5A, 300µs pulsed current in the wire and a 220A current in the solenoid magnet. In figure 5 we present a typical measurement of a cell magnetic flaw and the signal in the horizontal X direction with a 0.15A steering correction to cancel the magnetic tilt misalignment. The calibration of the tilt and offset is performed by moving the wire at various values to obtain the calibration curves by means of automatic micrometers. Figures 6, 7 show the offset and the tilt calibration curves with their measured signals. For an signal amplitude equal to 1 volt, we obtain an equivalent magnetic tilt and offset values of 800µrad and 350µm respectively. The sensitivity is around 50mV which corresponds to 40 µrad and 17 µm. The accuracy is estimated at 45 µm and 130µrad. In table 1 we present the results for the 32 first accelerator cells without steering corrections.

	Mean value	RMS	max.
Offsetx,y (µm)	30	45	90
tiltx,y(µrad)	700	400	1600

Table 1

By using steering corrections, the final tilt flaws are less than 130µrad. The steering currents are typically less than 0.5A for 220A solenoid magnet current, which correspond to a 1600 G magnetic field. A scale law has been established to adjust the steering current whatever the solenoidal current is. With the first 32 cells, the corresponding factor between the measured magnetic tilt and the steering current is (0.5 ± 0.05) mA/µrad.

3 CONCLUSIONS

The high quality beam requested for the AIRIX accelerator, leads us to use severe alignment specifications. We have demonstrated that the mechanical and the streched wire techniques with steering corrections are adapted to align accelerator cells within the specifications. However, these techniques need to take care of mechanical tolerances and assembly of the cells as well as to use solenoid magnet with homogenizing ring to produce acceptable field errors. Thanks to automatic procedures, we have increased the measured accuracy.

4 REFERENCES

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